An Examination of Houston's QuickRide Participants by Frequency of QuickRide Usage

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ABSTRACT

QuickRide is an innovative project designed to more effectively utilize the capacity of the high-occupancy vehicle (HOV) lanes on the Katy (I-10) and US 290 freeways in Houston. Under this project, two-person carpools can pay $2.00 to use the HOV lanes during the peak period, even though the lanes were normally restricted to vehicles with three or more occupants. This form of HOV lane is typically termed a high-occupancy / toll (HOT) lane and can be an effective travel demand management and congestion mitigation tool. However, relatively little is known about drivers who choose to use the HOT lane option. This paper examines the commute and socio-economic characteristics of Houston's QuickRide participants by their frequency of QuickRide usage. The study was based on a survey of QuickRide enrollees conducted in March 2003.

It was found that QuickRide participation increases with increasing trip length, perceived time savings, and frequency of trips in the travel corridor. Participation decreases with increasing carpool formation times but is generally irresponsive to minor changes in the $2.00 toll. QuickRide is also more likely to be used for commute trips than other trips. Socio-economic characteristics such as age, gender, annual household income, and education also have significant effects on QuickRide trip frequency. However, household size, vehicle availability, occupation, hourly wage rate, and whether or not a QuickRide participant shares the toll with his/her carpool partner do not significantly affect the level of participation.

Keywords: congestion or value pricing, HOT lanes, QuickRide, ordered logit model.

INTRODUCTION

In recent years, there has been growing interest in the use of high-occupancy/toll (HOT) lanes as an alternative to high-occupancy vehicle (HOV) lanes for managing traffic congestion and controlling air pollution (*1*). This interest in the concept of HOT lanes has resulted from an attempt to optimize the use of HOV lanes as well as growing public dissatisfaction and sometimes strong anti-HOV backlash (*2, 3, 4, 5*). Of particular concern is the so-called empty lane syndrome—where drivers are held up in traffic congestion on the main freeway lanes while adjacent HOV lanes are operating significantly below capacity. HOT lanes combine pricing strategies and occupancy restrictions to manage the number of vehicles using the facility. HOT lanes typically provide free or reduced-cost access to qualifying HOVs, while allowing other vehicles that do not meet occupancy levels required for free travel on the HOV the option of paying a toll to gain access to the HOV lanes (*6*).

Perez and Sciara (*6*) identified three main features that make the HOT lane concept appealing:

1. It expands mobility options in congested urban areas by providing an opportunity for reliable travel times to users prepared to pay a significant premium for this service;
2. It generates a new source of revenue which can be used to pay for transportation improvements, including enhanced transit service; and
3. It improves the efficiency of HOV facilities, which is especially important given the recent decline in HOV mode share in 36 of the 40 largest metropolitan areas (*5*).

HOT lanes are an example of the concept of *value pricing*, defined as 'a system of optional fees paid by drivers to gain access to alternative road facilities providing a superior level of service and time savings compared to the free facility' (*2*). Value pricing fundamentally differs from *congestion pricing* in its underlying purpose and intent. Traditional congestion pricing charges are meant to reduce peak period demand on heavily congested roads by charging a user fee. The intent of value pricing, however, is not to discourage drivers from using congested facilities but to offer them—for a fee—the option of alternative road facilities that provide a higher level of service. Unlike traditional toll roads that require all users to pay a fee, HOT lanes offer motorists a choice—staying in the slow-moving main lanes and traveling free versus paying a fee to enjoy a faster and less stressful travel in the adjoining HOT lanes (*2*).

At present, there are four HOT lane facilities operating in the world (*6, 7*). These include:

- State Route 91 (SR 91) Express Lanes – Orange County, California
- I-15 FasTrak – San Diego, California
- Katy Freeway QuickRide – Harris County, Texas, and
- Northwest Freeway (US 290) QuickRide – Harris County, Texas.

The SR 91 Express Lanes are a 10 mile (16.1 km), four-lane toll facility located in the median of the congested Orange County–Riverside County travel corridor. The project opened in 1995 as the first practical application of the concept of value pricing to a roadway facility in the United States (*7, 8*). As of August 2003, toll rates varied from \$1.00 to \$4.75 by time of day and day of week and vehicles with three or more occupants could use the facility at no cost during most periods of the day. Customers pay their toll from prepaid accounts using a FasTrak transponder. The Express Lanes facility provides average time savings of 12 to 13 minutes (*9*).

The I-15 FasTrak is an 8 mile (12.9 km), reversible, two-lane HOV facility in the median of I-15, about 10 miles (16.1 km)north of San Diego, California which opened in December 1996. HOV-2+ vehicles (vehicles with two or more persons) may use the facility at no cost. However, single-occupancy vehicles (SOVs) have to pay a toll that varies from \$0.50 to \$4.00, depending on the level of traffic, and may go up to as high as $8.00 in cases of severe congestion. Electronic signs located at the entrance to the HOT lanes give motorists advance notice of the current toll. Customers must have a FasTrak account to use the HOT lanes. Under the worst traffic conditions, FasTrak participants can save up to 20 minutes of travel time (*10*).

The Katy HOV lane opened in 1984. It is a 13 mile (20.9 km), one-lane reversible facility located in the median of Katy (I-10) Freeway in Houston, Texas. In the beginning only transit and vanpools could use the lane. However, restrictions were gradually reduced and, by 1986, stabilized at allowing HOV-2+ carpools. At the HOV-2+ restriction level the facility became highly congested during peak periods. To reduce congestion, the occupancy requirement was raised to HOV-3+ in 1988 during peak traffic periods (*11*). However, this change resulted in significant excess capacity in the HOV lane during the peak periods (*12*). In January 1998, the QuickRide program was introduced, which allowed a limited number of two-person carpools to use the Katy HOV lane. Under this program, two-person carpools can pay a toll of $2.00 to use the HOV lane during peak periods (6:45–8:00 AM and 5:00–6:00 PM), while HOV-3+ vehicles continue to use the facility for free. The $2.00 toll is charged electronically to drivers displaying both a QuickRide hang tag and a transponder. Participants receive an average travel time saving of approximately 17 minutes.

In view of the success of the Katy QuickRide program, the Metropolitan Transit Authority of Harris County converted the US 290 HOV lane to HOT use in November 2000 and it operates in similar manner to the Katy HOT lane facility, except that it is available only during the morning peak period (*11*). The afternoon peak period in this HOV lane is not congested and is open to HOV-2+ vehicles. It is a 15.5 mile (25.0 km), one-lane facility in the median of Northwest Freeway (US 290) which connects the northwest suburbs of Houston with downtown. Average travel time savings on the US 290 HOT lane is approximately 11 minutes.

A prominent feature of the QuickRide program is the fact that, unlike the two California projects where single occupant vehicles can use the HOT lanes for a fee, SOVs are not allowed to use the HOT lanes. This is a reflection of the HOT lane's limited capacity (one reversible lane) and the high travel demand on the Katy Freeway corridor—207,000 vehicles per day (*6*). QuickRide demand averaged 103 trips per day on the Katy HOT lane in 1998. After the introduction of QuickRide on US 290, total demand on the two facilities averaged 131 trips per day in 2000 and increased to 182 trips per day in 2002. These estimates are well below the targeted demand of 600 QuickRide vehicles per peak hour. In 1998, Stockton et al. conducted a survey to evaluate the effectiveness of the QuickRide program. Their study focused on issues such as the overall usage of QuickRide, changes in person throughput along the Katy Freeway corridor, and, to a lesser extent, the characteristics of QuickRide participants (*12*). However, their analyses were generally descriptive and based on a smaller sample size, whereas this research uses a larger sample size to determine significant differences between frequent, moderate, and infrequent QuickRide participants and develops a model to predict QuickRide use based on travel and socio-economic characteristics.

Building from the findings of Stockton et al. (*12*), recent analysis of QuickRide usage, and data from a recent survey of QuickRide enrollees, this study focuses on explaining the factors that underlie the decision to use QuickRide. The rest of this paper discusses the relevant theory behind the analyses, describes data and methods of analyses, presents analytical results, summarizes findings and conclusions, and makes recommendations for future research.

THEORY

The theoretical origins of travel demand estimation can be traced to consumer choice theory, which asserts that when faced with a number of possible alternatives the rational consumer makes the choice that maximizes his or her utility (or minimizes his or her disutility). The numerical value of the utility equation depends on the attributes of the available alternatives (for example, cost or travel time savings) and the trip maker (for example, income or age) and indicates how an individual ranks the set of alternatives and, hence, his or her preferred choice. The option with the highest utility is the travel choice that particular traveler is most likely to make. The option with the second highest utility is the next most likely choice and so on to the least likely. For QuickRide participants, the available modes for travel on the Katy Freeway corridor are: driving alone (not available on HOV lane), two-person carpools (available at all times on main lanes and during non-peak periods on HOV lane), QuickRide (two-person carpool + $2.00 toll during peak periods on HOV lane), 3+ person carpool, bus, and motorcycle. The utility for any particular mode is different for each individual. Greater understanding of these differences allows engineers and planners to develop programs that maximize the net societal benefits of the transportation system.

Standard multinomial logit modeling was used in this research. This model assumes that each decision-maker has a utility function (13):

$$U_j = \beta' X_j + \varepsilon_j \qquad (1)$$

where,

j = the set of alternatives available to the decision-maker,
X_j = a vector of measurable attributes of each travel option,
β' = a vector of the coefficients of X_j,
ε_j = unobservable factors, and
U_j = utility of decision-maker for travel option j.

The fact that the measured variables do not include everything relevant to the individual's decision makes the choice process probabilistic (*14*). It has been shown (*13, 14, 15, 16*) that the choice probability depends on the systematic utility differences as well as the distribution of the random (unobserved) utility differences. The most common model used is the *logit model,* which assumes that the random utilities follow the extreme value distribution (error terms are independently and identically distributed). The resulting choice probability is:

$$P_i = \frac{e^{\beta' X_i}}{\sum_{all\ j} e^{\beta' X_j}} \qquad (2)$$

In situations where the dependent variable is discrete and ordered in nature, the ordered logit model (a special case of logit models) is used. If, for example, there are three alternatives (for example 1 = poor, 2 = good, 3 = excellent), then two cut-off points (μ_0 and μ_1) can be estimated using maximum likelihood estimation. The decision is then represented as:

"poor" if $U_j < \mu_0$
"good" if $\mu_0 < U_j < \mu_1$
"excellent" if $U_j > \mu_1$

Using these cut-off points the probability of an alternative being chosen is estimated as follows (*13*):

$$P_1 = \frac{1}{1+e^{-(\mu_0 - \beta' X_j)}} \tag{3}$$

$$P_2 = \frac{1}{1+e^{-(\mu_1 - \beta' X_j)}} - P_1 \tag{4}$$

$$P_3 = 1 - (P_1 + P_2) \tag{5}$$

where,

P_i = the probability of choosing alternative i (i = 1,2,3),

μ_0, μ_1 = the two cut-off points.

METHODOLOGY

To begin, descriptive statistics of all survey respondents were examined to obtain an overall view of respondents. Respondents were then divided into three groups based on their frequency of QuickRide usage. It should be noted here that since QuickRide operates only in the morning peak period on US 290, fewer trips were expected there than on Katy Freeway, where QuickRide operates during both the morning and afternoon peak periods. The three groups of respondents were (all trips are one-way):

1. Infrequent participants, defined as QuickRide enrollees who indicated they took a maximum of one QuickRide trip on either route (Katy or US 290) in the week immediately preceding the survey,

2. Mid-level participants, defined as QuickRide enrollees who indicated they took 2–4 QuickRide trips on Katy or 2–3 QuickRide trips on US 290 in the week immediately preceding the survey, and

3. Frequent participants, defined as QuickRide enrollees who indicated they took 5–10 QuickRide trips on Katy or 4–5 QuickRide trips on US 290 in the week immediately preceding the survey.

To answer the fundamental question of whether or not there were significant differences ($p < 0.05$) between respondents in the three groups, several statistical tests were used. For *categorical* responses (for example, trip purpose or occupation), the chi-square contingency test was used. One-way analysis of variance (ANOVA) was used for three-way comparison of means of *continuous* data (for example, travel time savings or trip length). For *ordinal* data the Kruskal Wallis test for three-way comparison of means (for example, age or income) was employed.

An ordered logit model was then formulated with frequency of QuickRide participation as the dependent variable. The explanatory variables used in the model, their measurements, and expected (hypothesized) impact on QuickRide trip frequency are summarized in Table 1. The hypotheses were formulated based on intuitive reasoning and a thorough review of carpooling literature.

DATA

To gather the data required for a greater understanding of HOT lane use and build the models outlined above, a survey was mailed to all 1459 people enrolled in QuickRide as of December 2002. The survey included 36 questions regarding QuickRide enrollees' QuickRide and non-QuickRide trips, their typical use of QuickRide, feelings toward alternate QuickRide tolling schemes, and their socio-economic characteristics. The survey was mailed in March 2003. Surveys returned by the beginning of April were included in the analysis (responses in the 14 surveys returned later may have been influenced by a QuickRide price change in April and were not included). A total of 93 surveys were returned by the post office due to incorrect addresses. Of the remaining 1366 surveys, 525 were returned on time for a 38.4 percent response rate (*17*).

Three slightly different surveys were mailed to QuickRide participants. The questions regarding the respondents' most recent trip varied based on QuickRide movement (Katy AM, Katy PM, or US 290). The surveys were target mailed to the respondents based on their usage of these different QuickRide movements. In this manner respondents could specifically answer questions directed at their typical travel behavior, shortening and simplifying the survey instrument.

Once the data were entered and any data entry errors corrected, the surveys were weighted based on respondents' stated number of weekly QuickRide trips as compared to the average number of QuickRide trips that participants actually made per week during the last three weeks of March 2003. It was necessary to weight the surveys to account for both response bias and ex-post rationalization in survey responses. Both errors were expected as (a) participants who frequently used QuickRide were likely to be more interested/invested in the QuickRide program and therefore more likely to respond, and (b) respondents often overstate their actual participation rate. Based on the respondents' stated use of QuickRide it was fairly obvious both types of errors existed. To account for these biases, the surveys were weighted such that the proportions of survey respondents who indicated taking a specific number of QuickRide trips on a specific freeway equaled actual average QuickRide usage on that freeway for the last 3 weeks in March (see equation 6).

$$W_{i,j} = \frac{T_{i,j}}{R_{i,j}} \tag{6}$$

where,

$W_{i,j}$ = weighting factor for surveys on road i indicating a weekly usage of j,
$T_{i,j}$ = number of enrollees who averaged j QuickRide trips per week (based on the last three weeks preceding the survey) on freeway i based on QuickRide billing records,
$R_{i,j}$ = number of respondents on freeway i who indicated they made j QuickRide trips in the week immediately preceding the survey,
i = 1 for Katy Freeway and 2 for US 290, and
j = 0–10 for Katy Freeway and 0–5 for US 290.

The resulting weights are shown in Table 2. Based on these data it was clear that infrequent participants (0–1 trips per week) were significantly underrepresented in survey responses and frequent participants (7–10 trips per week on Katy and 5 trips per week on US 290) were considerably overrepresented. This indicates three potential sources of error: (a) the small number of infrequent participants who responded were not representative of all infrequent participants; (b) some frequent participants were actually less frequent than indicated, skewing the characteristics of this group, and (c) some frequent participant's transponders were not registering with the automatic vehicle identification (AVI) equipment (this concern is very likely and the research team is examining possible remedies). Without knowing the true number of trips made by each survey respondent (which cannot be determined since survey responses were anonymous), the best way to attempt to minimize the impact of these potential errors is through the weighting efforts described earlier.

It should also be noted that several US 290 survey respondents indicated more than five QuickRide trips per week. It was felt the most likely reason for this was confusion between using QuickRide and simply driving on the HOT lane in the afternoon (when QuickRide does not operate) and some respondents counted these afternoon trips when they should not have. Therefore, the stated number of weekly trips was divided by two for these respondents. Also, three respondents for US 290 and three for Katy indicated more than 10 QuickRide trips per week. These responses were removed from the analysis, thus reducing the available data to 519 responses. This analysis was limited to the respondents who either stated the number of QuickRide trips they made in the week immediately preceding the survey or stated the average number of QuickRide trips they made in a month or year. In all, eight respondents did not answer this question. Hence, the total number of cases available for our analysis was reduced to 511.

Aside from this survey, several other sources of data were available for this analysis, including:

1. A data set containing the transponder number, date, and time of every QuickRide trip ever taken. This data set was used to build the weights described above.
2. A data set containing travel speeds on both the main (free) lanes and the HOT lanes on US 290 and Katy Freeway. The travel speeds provided detailed information on the travel time savings gained through the use of QuickRide.
3. Survey results from a smaller survey of QuickRide enrollees conducted in 1998.

RESULTS

Table 3 provides a summary of descriptive statistics and statistical analysis of respondents' socio-economic and commute characteristics.

Individual Demographics

Frequent and mid-level QuickRide participants were significantly more likely to be 35 to 44 years old and significantly less likely to be 65 or more years old. Females represented 53.0 percent of all respondents. There were significantly more females than males in the mid-level and frequent participants group than in the infrequent participants group. Most respondents have an education beyond high school. College graduates or those with some college/vocational education were, however, significantly more likely to be mid-level to frequent participants than postgraduate degree holders. About 65 percent of respondents were employed in professional/managerial positions. Administrative/clerical workers were significantly more likely to be mid-level or frequent participants. Most respondents (22 percent) earned between \$30.01 and \$40.00 per hour in 2002. This was representative of the infrequent participants but not mid-level and frequent participants, most of whom earned between \$20.01 to \$30.00 per hour.

Household Characteristics
Respondents reported an average of 2.99 persons per household with no significant differences between the three groups of participants. About 90 percent of respondents were married. Of these, 67 percent were married with child(ren). There were, however, more unrelated adults among the frequent participants than infrequent to mid-level participants. There were slightly more single-parent families among the mid-level and frequent participants than among infrequent participants. There was an average of 2.32 vehicles per household with no significant differences among the various groups. Only about 7 percent of respondents reported an annual household income below $50,000. About 62 percent of respondents stated an annual household income of $100,000 or more. Although rather high, it is not surprising as drivers in this corridor generally have higher than average incomes.

Commute Characteristics

Trip Purpose
A very high proportion (67 percent) of travelers in the data set were commuting when they used QuickRide. An even higher proportion of mid-level (90 percent) and frequent (83 percent) participants were on commute trips. No recreational trips were made by mid-level and frequent participants, whereas about 12 percent of infrequent participants' trips were for recreational purposes. Trips made to schools were significantly lower among mid-level participants than infrequent or frequent participants. Due to the location of a school near an exit on both freeways, it was not surprising frequent QuickRide participants were on a school-related trip. In fact a clear decrease in AM QuickRide participation occurs during school holidays.

QuickRide Trip Length
The trip length of respondents varied between 15 and 105 minutes with an average of 45.3 minutes. Mid-level participants made significantly longer trips than both frequent and infrequent participants, with infrequent participants making the shortest trips. It should be noted that some respondents reported unusually high trip lengths. All trip lengths greater than or equal to 120 minutes were considered unreasonable for travel in the Houston metropolitan area and were rejected as extreme values (19 responses were rejected based on this criteria).

Perceived QuickRide Time Savings
Respondents perceive an average QuickRide travel time savings of 29.8 minutes, which is significantly higher than the actual values of 17.33, 15.04, and 10.51 minutes recorded for the Katy AM, Katy PM, and US 290 QuickRide periods, respectively. This was not surprising since QuickRide participants may be trying (subconsciously) to justify their choice. Similar results have been reported in other studies. Billheimer (*18*) reported that drivers in carpool lanes in the San Francisco Bay area perceived HOV time savings that were more than double the average savings recorded during the heaviest traffic period. As in Billheimer's study, mid-level and frequent QuickRide participants reported QuickRide travel time savings of more than 34 minutes (more than double that recorded on either Katy (AM/PM) or US 290), with infrequent participants reporting a perceived travel time savings of 28.7 minutes.

Usual Carpool Partner and Carpool Formation Time
Most respondents carpooled with a coworker (40.6 percent), an adult family member (35.9 percent), or a child (24.7 percent). Note that these percentages exceed 100 as they include respondents that selected multiple carpool partner types. Mid-level participants were significantly more likely to carpool with an adult family member or neighbor than both frequent and infrequent participants. Respondents spent up to 23 minutes to pick up and drop off their carpool partners, with an average carpool formation time of 4.33 minutes. Mid-level and frequent participants were significantly more likely to spend more time forming carpools (5.32 minutes) than infrequent participants (4.14 minutes). One possible explanation would be that mid-level and frequent QuickRide participants have established carpools while infrequent participants only carpool when very convenient and therefore have low average formation times. Frequent and midlevel participants had significantly higher carpool formation times than infrequent participants when carpooling with a child or an adult family member (see Figure 1).

Frequency of Travel in the Katy/US 290 Freeway Corridor
The average number of one-way trips on both freeways, irrespective of travel mode, was 7.3 per week. Frequent QuickRide participants reported more trips on the corridors than mid-level participants, who in turn made more trips on the corridors than infrequent QuickRide participants.

Passenger's Contribution to Toll
Approximately 51 percent of frequent participants, 33 percent of mid-level participants, and 25 percent of infrequent participants said their carpool partners helped pay the $2.00 QuickRide toll. An average of 50.3 percent and 43.2 percent of all respondents shared the toll with their passengers when traveling with either a coworker or an adult family member, respectively, while only 5.5 percent of all respondents who traveled with casual carpoolers shared the toll with their passengers. Almost no respondent who traveled with a child or a neighbor shared the toll with the passenger.

Number of QuickRide Trips for Various Tolls Other Than $2.00
Respondents were asked the number of trips they would make per week if the QuickRide toll was $1.00, $1.50, $2.50, and $3.00. They were also asked to state the number of trips they would make if two-person carpools were allowed to use the HOV lane without paying a fee. As expected, the average number of trips decreased as the toll increased. Moreover, frequent participants consistently stated a higher number of trips than mid-level participants, who also stated more trips than infrequent participants. This suggests that varying the toll in the stated range is not likely to change the proportion of participants in the three groups. Additionally, at the various toll levels, there were small changes in number of QuickRide trips indicating inelastic responses to the toll (see Figure 2).

Ordered Logit Model of QuickRide Trip Frequency
Various combinations of independent variables were tested in the ordered logit model. However, only those variables that were significant at the 5 percent level and showed negligible correlation with other variables were used in the final model. Limdep 7.0 software was used for model estimation. Table 4 provides a summary of the modeling results.

As hypothesized, QuickRide participation increases with commute characteristics such as commute trips, trip length, perceived travel time savings, and frequency of travel in the Katy or US 290 travel corridor. These results appear reasonable. For example, commute trips are usually time constrained and participants are likely to derive maximum benefits from using QuickRide. Since the $2.00 QuickRide toll is relatively small compared to the overall cost of a long trip (*1, 8*) it is not surprising that QuickRide trip frequency increases with increasing trip length. It is also reasonable that the program would be more attractive to participants who perceive greater QuickRide travel time savings than those who perceive little or no travel time savings. The finding that QuickRide trip frequency increases with frequency of use of the travel corridor (irrespective of travel mode) is also not surprising since frequent travelers would generally be more acquainted with traffic conditions in the corridor than occasional travelers (*1*).

Socio-economic characteristics such as age, gender, annual household income, household type, and education also have a significant effect on QuickRide trip frequency. The results indicate that participants between 25 and 54 years of age are likely to use QuickRide more frequently than both young adults and persons over 54 years of age. Contrary to our a priori belief that higher-income households would make more QuickRide trips than lower-income households, the model estimation results show that participants with annual household incomes of $50,000 or less are more likely to use QuickRide than those with household incomes in excess of $50,000 per year. A plausible reason is that high income earners generally have job security and flexible schedules and can afford to be late for work or shift their travel times to the non-peak periods. The results also indicate that participants who are married with at least one child are less likely to use QuickRide, while having a college degree increases the probability of using QuickRide.

Household size, vehicle availability, occupation, and hourly wage rate are not significant at the 5 percent level. Also, whether or not a QuickRide participant shares the toll with his/her carpool partner does not significantly affect the frequency of participation.

The negative constant term is also reasonable and suggests that all things being equal, drivers are more likely to be infrequent participants of QuickRide. This result is consistent with QuickRide usage data that showed approximately 84 percent of QuickRide enrollees averaged between 0 and 1 QuickRide trips per week in 2002. Approximately 11 percent averaged between 1 and 2 trips per week and only 5 percent averaged more than 2 trips per week. (Note that this level of recorded participation may be slightly lower than actual usage due to the missed transponder reads, as mentioned earlier.)

SUMMARY AND CONCLUSIONS

The United States' experience with HOT lanes continues to grow with three projects in Houston, San Diego, and Riverside County being fairly well established. After 5 years in operation (3 years on US 290), the Houston QuickRide program receives comparatively lower patronage than the two California projects. Standard statistical methods and an ordered logit model were used in this study to examine the characteristics of infrequent and frequent QuickRide participants as a step in understanding the reasons for the low patronage.

The results indicate that the disutility of forming a carpool is a major deterrent to participation in the program. Conversely, inelastic response to minor changes in the toll, coupled by responses to a question regarding participants feeling towards the $2.00 toll, suggests that the toll is not a major deterrent to participation. The results also show that females, participants with college education, those with annual household income below $50,000, those on commute trips, and those between 25 and 54 years old are likely to make more QuickRide trips. Whether or not a participant shares the QuickRide toll with his/her carpool partner does not significantly affect the level of participation. It was also found that participants who perceive higher QuickRide travel time savings, travel on the corridor more frequently, and/or undertake longer trips are likely to use QuickRide more often.

A more comprehensive study of QuickRide participant's travel behavior that incorporates major issues such as the value of time of different groups of enrollees, their disutilities for carpooling, and a more detailed analysis of toll price elasticities is recommended. A comparative analysis of current enrollees, former enrollees, non-users, and participants in the California HOT lanes will also shed more light on driver's use of HOT lanes and the decisions behind their participation. Such studies will further help engineers and planners to understand the reasons behind drivers' decision to use QuickRide, determine optimal tolling levels, formulate more appropriate marketing strategies, and, most importantly, improve the overall efficiency of these programs to maximize the net benefits derived from travel.

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REFERENCES

1. Li, J. Explaining High-Occupancy Toll Lane Use. *Transportation Research Part D*. 6, Pergamon, Amsterdam, 2001, pp. 61-74.

2. Poole, R. W., Jr., and C. K. Orski. Building a Case for HOT Lanes: A New Approach to Reducing Urban Highway Congestion. *Reason Public Policy Institute*. Policy Study No. 257, 1999. www.rppi.org. Accessed May 15, 2003.

3. Kim, E. J. *HOT Lanes: A Comparative Evaluation of Costs, Benefits and Performance*. Ph.D. Dissertation. University of California at Los Angeles, California, 2000.

4. Dahlgren, J. Are HOV Lanes Really Better? *Access,* Vol. 6. California, Spring 1995, pp. 25-29.

5. Poole, R. W. New Research on HOT Lanes. *Reason Public Policy Institute,* August 2002. http://www.rppi.org/researchonhotlanes.html.
Accessed May 13, 2003.

6. Perez, B. G., and G. -C. Sciara. *A Guide for HOT Lane Development*. FHWA-OP-03-009FWHA, Federal Highway Administration, Washington, D.C., 2003.

7. Burris, M.W., and R. M. Pendyala. Discrete Choice Models of Traveler Participation in Differential Time of Day Pricing Programs. *Transport Policy,* Vol. 9, No. 3, 2002, pp. 241-251.

8. Sullivan, E. *Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes: Final Report.* Department of Civil and Environmental Engineering, California Polytechnic State University at San Luis Obispo, California, 2000.
http://ceenve.calpoly.edu/sullivan/sr91/sr91.htm.
Accessed July 9, 2003.

9. Sullivan, E. *Evaluating the Impacts of the SR 91Variable-Toll Express Lane Facility: Final Report.* Department of Civil and Environmental Engineering, California Polytechnic State University at San Luis Obispo, California, 1998.
http://ceenve.calpoly.edu/sullivan/sr91/sr91.htm.
Accessed July 9, 2003.

10. Supernak, J., C. Kaschade, D. Steffey, and G. Kubiak. *I-15 Congestion Pricing Project, Monitoring and Evaluation Services, Phase II Year Three Traffic Study*, 2001.
http://www.sandag.org/fastrak/pdfs/yr3_traffic.pdf.
Accessed June 10, 2003.

11. Burris, M. W., and R. L. Hannay. Equity Analysis of the Houston QuickRide Project. Presented at 82nd Annual Meeting of the Transportation Research Board. Washington, D.C., 2003.

12. Stockton, W., N. Edmonson, P. Hughes, M. Hickman, D. Puckett, Q. Brown, A. Miranda, and S. W. Shin. *An Evaluation of the Katy Freeway HOV Lane Pricing Project*. Report E 305002, Texas Transportation Institute, College Station, Texas, 2000.

13. Train, K. E. *Discrete Choice Methods with Simulation*. Cambridge University Press, Cambridge, UK, 2003.

14. Small, K. A. *Urban Transportation Economics*. Hardwood Academic Publishers, Philadelphia, Pennsylvania, 1992.

15. Small, K. A., and C. Winston. The Demand for Transportation: Models and Applications. In: Gomez-Ibanez, J., W. B. Tye, and C. Winston, Eds. *Essays in Transportation Economics and Policy. A Handbook in Honor of John R. Meyer*. Brookings Inst. Press, Washington, D.C., 1999, pp. 142–147.

16. Ben-Akiva, M., and R.S. Lerman. *Discrete Choice Analysis: Theory and Application to Travel Demand*. Massachusetts Institute of Technology Press, Cambridge, Massachusetts, 1985.

17. Richardson, A. J., E. S. Ampt, and A. H. Meyburg. *Survey Methods for Transport Planning*. Eucalyptus Press: Melbourne, Australia, 1995.

18. Billheimer, J. W. *San Francisco Bay Area HOV Lane User Study: Final Report*. Prepared for the Metropolitan Transportation Commission by SYSTAN, Inc., Los Altos, California, 1990. In: Dowling, R. G., J. Billheimer, V. Alexiadis, and A. D. May. Predicting High Occupancy Vehicle Lane Demand, Federal Highway Administration, Washington, D.C., 1996, pp. 3.1-3.6.

LIST OF TABLES AND FIGURES

TABLE 1 Definitions and Measurements of Explanatory Variables Used in Logit Model

Variable	Measurement	Predicted Effect*
Commute trip	1, if trip purpose = commute 0, otherwise	+
Trip length	QuickRide travel time (minutes)	+
Time savings	Perceived QuickRide time savings (minutes)	+
Carpool formation time	Time to pick up/drop off carpool partner (minutes)	–
Frequency of travel in corridor	Total number of one-way trips per week in corridor	+
Partner's contribution	1, if carpool partner helps pay toll 0, otherwise	+
Household size	Number of people per household	+
Vehicle availability	Number of vehicles per household	–
Low income	1, if household income (2002) less than $50,000 0, otherwise	–
Age	1, 25 to 54 0, 16 to 24 or 55 and older	+
Hourly wage rate	1, less than $20 per hour 0, $20 or more per hour	–

* A '+' indicates the variable was predicted to increase the frequency of participation in QuickRide. The opposite effect was predicted for those variables with a '-'sign.

TABLE 2 Number of QuickRide Participants Making a Specific Number of Trips per Week

Number of trips per week	Katy			US 290		
	Stated ($R_{1,\ j}$)	Observed ($T_{1,\ j}$)	Weight ($W_{1,\ j}$)	Stated ($R_{2,\ j}$)	Observed ($T_{2,\ j}$)	Weight ($W_{2,\ j}$)
0–0.49	36	709	19.6944	10	396	39.6000
0.5–1.49	51	83	1.6275	31	43	1.3871
1.5–2.49	38	54	1.4211	19	30	1.5789
2.5–3.49	20	32	1.6000	23	20	0.8696
3.5–4.49	22	26	1.1818	23	19	0.8261
4.5–5.49	35	17	0.4857	86	9	0.1047
5.5–6.49	19	9	0.4737			
6.5–10	98	12	0.1224			

TABLE 3 Socioeconomic and Commuting Characteristics of Survey Respondents by Frequency of Participation

Characteristic (Percent of Respondents in Each Category)	Frequency of QuickRide Use: All Participants (N = 1459)[b]	Infrequent Participants Katy: 0–1 trips/week US 290: 0–1 trips/week (N = 1231)	Mid-level Participants Katy: 2–4 trips/week US 290: 2–3 trips/week (N = 162)	Frequent Participants Katy: 5–10 trips/week US 290: 4–5 trips/week (N = 66)
QuickRide trip purpose*				
Commute*	66.7	61.7	89.9	82.5
Recreation*	9.9	12.2	0	0
Work	4.1	4.6	2.7	0
School*	11.0	11.6	5.4	15.9
Other*	8.3	9.9	2.0	1.6
QuickRide trip length (minutes)[a]	45.32	44.70	49.37	44.78
Total trips/week on corridor[a]*	7.32	7.04	8.47	9.75
QuickRide trips/week[a]*	0.64	0.1	2.64	5.65
Perceived travel time savings[a]*	29.77	28.71	35.29	34.22
Usual carpool partner*				
Coworker	40.6	40.4	40.4	42.4
Neighbor*	2.8	1.9	8.6	6.1
Adult family member*	35.9	34.5	46.3	36.4
Casual carpool (slug)	7.1	7.4	6.2	4.5
Child	24.7	25.7	17.3	25.8
Other	4.8	5.1	2.5	3.0
Extra time to pick up/drop off QuickRide partner[a]*	4.33	4.14	5.32	5.32
Passenger's contribution to toll*				
Passenger helps pay toll	26.8	24.5	33.3	50.8
Passenger does not help pay toll	73.2	75.5	66.7	49.2
Impression about $2.00 toll				

	Frequency of QuickRide Use			
Characteristic (Percent of Respondents in Each Category)	**All Participants (N = 1459)[b]**	**Infrequent Participants Katy: 0–1 trips/week US 290: 0–1 trips/week (N = 1231)**	**Mid-level Participants Katy: 2–4 trips/week US 290: 2–3 trips/week (N = 162)**	**Frequent Participants Katy: 5–10 trips/week US 290: 4–5 trips/week (N = 66)**
Very reasonable	26.9	27.8	22.8	21.2
Somewhat reasonable	29.5	28.3	36.4	34.8
Neutral	22.1	21.7	22.8	27.3
Somewhat unreasonable	19.0	20.1	14.2	12.1
Very unreasonable	2.5	2.2	3.7	4.5
QuickRide trips at various tolls[a]				
Free*	3.03	2.7	4.08	5.74
$1.00*	2.50	2.12	3.88	5.66
$1.50*	2.23	1.88	3.34	5.20
$2.50*	1.38	1.07	2.36	4.2
$3.00*	1.27	1.05	1.95	3.35
Age*				
16 to 24	3.4	3.3	4.3	3.0
25 to 34	14.3	14.0	16.1	15.2
35 to 44*	26.0	24.2	36.0	33.3
45 to 54	38.4	38.9	36.0	36.4
55 to 64	11.6	12.3	6.8	10.6
65+*	6.2	7.3	0.6	1.5
Gender*				
Male	47	48.5	39.6	37.9
Female	53	51.5	60.4	62.1
Household type*				
Single adult	5.7	5.4	6.9	9.0
Unrelated adults*	0.4	0.2	0.6	4.5

Characteristic (Percent of Respondents in Each Category)	Frequency of QuickRide Use All Participants (N = 1459)[b]	Infrequent Participants Katy: 0–1 trips/week US 290: 0–1 trips/week (N = 1231)	Mid-level Participants Katy: 2–4 trips/week US 290: 2–3 trips/week (N = 162)	Frequent Participants Katy: 5–10 trips/week US 290: 4–5 trips/week (N = 66)
Married without child	29.9	30.8	29.4	14.9
Married with child(ren)	60.5	60.7	57.5	62.7
Single parent family*	1.7	1.0	5.0	6.0
Other	1.7	1.8	0.6	3.0
Household size[a]	2.99	2.99	3.05	2.99
Vehicles per household[a]	2.32	2.30	2.44	2.27
Occupation*				
Professional/Managerial	64.8	65.2	62.2	64.6
Technical	10.1	10.6	8.3	4.6
Sales	5.5	5.5	5.8	4.6
Administrative/Clerical*	9.3	7.9	16.7	16.9
Manufacturing	0.0	0.0	0.0	0.0
Stay-at-home parent*	0.4	0.3	0.6	3.1
Unemployed/Seeking work	1.6	1.8	0.6	0.0
Other	8.4	8.8	5.8	6.2
Last year of school completed*				
Less than high school*	0.2	0.0	1.3	1.5
High school graduate	8.8	9.1	8.1	6.1
Some college/Vocational*	17.0	15.8	21.3	28.8
College graduate*	38.6	37.2	46.3	45.5
Postgraduate degree*	35.3	37.9	23.1	18.2
Hourly wage rate (per hour)				
Less than $10	3.8	4.3	1.4	1.9
$10.01 to $15	7.8	8.4	3.6	7.4

Characteristic (Percent of Respondents in Each Category)	Frequency of QuickRide Use All Participants (N = 1459)[b]	Infrequent Participants Katy: 0–1 trips/week US 290: 0–1 trips/week (N = 1231)	Mid-level Participants Katy: 2–4 trips/week US 290: 2–3 trips/week (N = 162)	Frequent Participants Katy: 5–10 trips/week US 290: 4–5 trips/week (N = 66)
$15.01 to $20*	7.8	6.9	12.9	9.3
$20.01 to $30*	17.0	16.0	19.4	27.8
$30.01 to $40	22.2	23.5	17.3	13.0
$40.01 to $50*	8.9	7.9	14.4	13.0
$50.01 to $60	10.5	11.4	6.5	5.6
$60.01 to $100	8.1	8.1	8.6	7.4
Over $100	13.9	13.6	15.8	14.8
Annual household income*				
Less than $10,000*	0.1	0.0	0.7	0.0
$10,000 to $14,999	0.0	0.0	0.0	0.0
$15,000 to $24,999*	0.1	0.0	0.7	0.0
$25,000 to $34,999	2.0	2.1	1.3	1.7
$35,000 to $49,999	4.6	4.2	7.4	5.2
$50,000 to $74,999	13.7	13.1	15.4	19.0
$75,000 to $99,999	17.8	17.7	18.8	17.2
$100,000 or more	61.7	62.9	55.7	56.9

Notes to Table 3

No response data were excluded by individual question number; therefore the sum of respondents from individual categories may not equal the total of all respondents. Multiple responses were allowed for usual carpool partners and hence the sum of percentages of responses for all categories exceeds 100 percent.

* Significant difference (at the 0.05 level) between groups of survey respondents. Statistical tests used included:

- Kruskal-Wallis for 3-way comparison (by group number) of ordinal data (for example; age, education, and income).
- One-way ANOVA for 3-way comparison (by group number) of continuous data (for example; trip length, travel time savings).
- Chi-square test for 3-way comparison of nominal data (for example; trip purpose, gender, household type, and occupation).

a. These entries represent mean responses (not proportions).

b. N values based on weighted data. Actual number of surveys was 128, 122, and 261 for infrequent, mid-level, and frequent participants, respectively.

TABLE 4 Model Estimation Results

Variable	Coefficient	Standard Error	t-stat	p-value
Constant	-4.8166	0.3048	-15.802	0.0000
Commute trip	1.5197	0.1401	10.844	0.0000
Trip length	0.0226	0.0032	6.948	0.0000
Time savings	0.0102	0.0040	2.560	0.0105
Frequency of travel in corridor	0.1158	0.0143	8.099	0.0000
Low income	0.4980	0.1664	2.993	0.0028
Married with child(ren)	-0.6236	0.1273	-4.897	0.0000
Age (25–54)	0.5449	0.1399	3.894	0.001
Gender (male)	-0.2723	0.1216	-2.240	0.0251
College education	0.2073	0.0756	2.742	0.0061
Cut-off point 1 (Infrequent to mid-level participation)	0 (by default)			
Cut-off point 2 (Mid-level to frequent participation)	1.5719	0.1900	8.272	0.0000
	Summary Statistics			
Number of observations		378		
Log likelihood function		-209.7810		
Restricted log likelihood		-381.0114		
Chi-squared		342.4607		
Significance level		0.0000		

FIGURE 1 Carpool formation times for various carpool compositions.

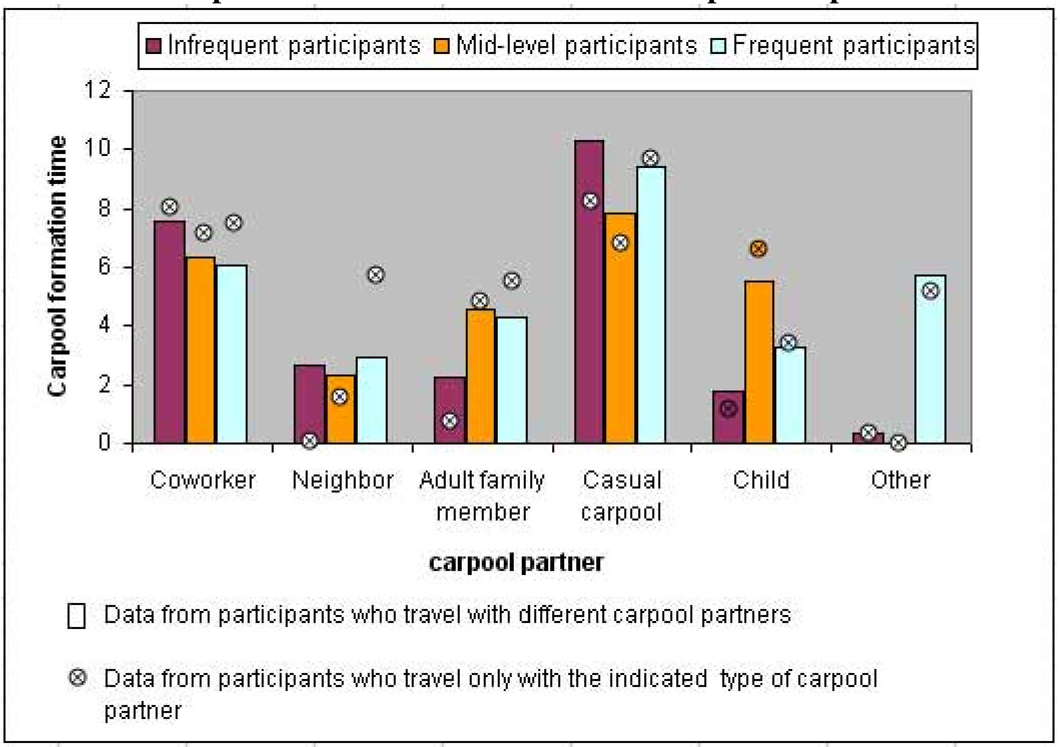

FIGURE 2 Stated number of QuickRide trips at various toll levels.